The Best (Research) Is Yet to Come

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I took the opportunity recently to review several new reports that summarize progress and then recommend directions for basic oceanographic research during the next 5-10 years. My first impression was that the results obtained during the recent past are a tough act to follow. Paradigm shifts, new discoveries, new technologies and major breakthroughs were common during the past 20 years. Since graduate school, I personally witnessed the emergence of many new ideas, concepts or technologies including plate tectonics, microbial loop, vent communities, carbon cycle and climate change, role of iron and satellite oceanography, to name just a few. Will this incredible pace continue into the future? I believe it will and will highlight just a few areas ready for rapid progress and exciting new findings.

Open ocean food webs are based on the small organisms comprising the microbial loop, yet the two key groups of photosynthetic organisms at its base (Cyanobacteria and Prochlorococcus) were discovered and described only within the past two decades. Marine ecologists are now turning increasing attention to the organisms and biogeochemical processes of the "Twilight Zone"—mid-waters well below the depth of sunlight penetration. Recent work suggests that bacteria-like Archaea are the dominant group of organisms in these waters, and virtually nothing is known of their ecology. Geologists and biologists are interested in another recently discovered group of marine organisms—the deeply buried biosphere. These microbes were discovered only during the past decade and are found buried in the rock tens to hundreds of meters beneath the sea floor. Their ecology, physiology, role in biogeochemical cycles and even their global abundance are substantially unknown and will be a focus for the next phase of ocean drilling. We thus have only the most basic knowledge of the complex interactions defining food web and biogeochemical processes, from the euphotic zone to deep-sea sediments, in most of the global ocean. Most of what we do know was discovered in the past decade or two, and I do not anticipate a break in this rapid pace of discovery.

A report from the National Academy of Sciences recently reviewed and discussed the human health benefits from ocean research. To date, several beneficial compounds, including antiviral and anticancer drugs, were found and then extracted from marine organisms. Some of these led to new products or will do so soon. Most experts believe that we have barely scratched the surface in this area, and many more useful compounds will be discovered with new research. The stakes are very high, and one can imagine the impact on our field as new and significant compounds are discovered and come to market to affect human health.

New technologies are revolutionizing physical oceanography, as well as ocean geophysics. In the near future, large-scale deployment of ocean drifters will track ocean currents to provide profiles of seawater density and other ocean properties for the global ocean. Shore- and buoy-based radars will routinely map coastal surface currents at or below the kilometer scale. High-resolution numerical models will assimilate these and other data, including measurements from the next generation of satellite altimeters, to provide a new view of ocean circulation down to the scale of ocean eddies and river plumes. Such models will help predict the pace and effects of ocean climate change, as well as the important characteristics of coastal ocean circulation. Multi-beam sonar now map the seafloor with meter-scale resolution revealing remarkable detail. The images will significantly impact fields as diverse as geophysics, marine archeology and benthic ecology. Not to mention marine navigation. I doubt a ship like the *QE2* will ever again hit an uncharted reef, once multi-beam mapping of the coastal zone is complete and the resulting high resolution charts are in general use.

As a final example, we need to understand how human activities are affecting global climate and the effects of climate change on the ocean. Specifically, oceanographers need credible models for describing the future state of the ocean, and of ocean ecosystems, as the Earth warms. It's a stretch to expect elected officials to ask U.S. voters and industry to switch to energy efficient life styles and products, if researchers cannot provide hard scientific evidence as to the consequences for not doing so. Accurate predictions of what could happen to ocean circulation and ocean ecology in response to different scenarios for future fossil fuel consumption and net CO_2 release could be the most important legacy of the next 5-10 years of ocean research.